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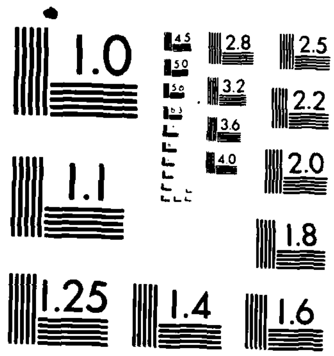

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Two methods are identified to improve the performance of a network design algorithm in terms of lower number of inter-switch trunks and better point-to-point grades of service. This report outlines both the methods and presents the improvements that can be achieved in the European AUTOVON network for the assumed traffic load.

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SEPTEMBER 1985

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FOREWORD

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SUMMARY

The existing program for the design of OS/AUTOVON networks determines the link sizes for the given network connectivity, traffic loads, routing plan and link blocking probabilities. If the resulting point-to-point loss probabilities are unacceptably high or too low (resulting in large link sizes), the link blocking probabilities need manual adjustment. The desired adjustment is not known and can only be assessed by experimenting with a large number of sets of link blocking probabilities and examining the resultant link sizes and point-to-point loss probabilities.

Our search for methods to automatically resize the links using the feedback principle and thereby improve the design of a network led to identification of two methods: (1) Link GOS Adjustment method and (2) Link Size Adjustment method. Test results showed that the first method can effectively bring the point-to-point loss probability of traffic to within the specified GOS with fewer interswitch trunks. The second method maximized the number of source-destination pairs whose point-to-point loss probabilities are between the specified lower and upper bounds, although it involved more hops for completed calls and more interswitch trunks.

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I. INTRODUCTION

The logic of the existing algorithm for the design of the AUTOVON networks in the Pacific and European regions is explained in the Technical Note No. 1-73, "Circuit Switched Network Performance Algorithm (Mod I)," prepared by Dr. M. J. Fischer and Mr. J. E. Knepley. The algorithm is based on the technique developed by Mr. Steven Katz of Bell Laboratories [1]. Dr. G. Swinsky has recently adapted the algorithm to consider links in both terrestrial and satellite media.

The inputs for the algorithm, shown in Figure 1, are:

(i) network connectivity
(ii) traffic loads
(iii) routing plan for the traffic flow and
(iv) initial link blocking probabilities.

The main outputs are the link sizes and the average point-to-point loss probabilities. The algorithm has the option to input the link sizes, in which case the initial link blocking probabilities will not influence the final point-to-point loss probabilities.

The fourth input, the initial link blocking probabilities, is not part of design specification but is required by the existing algorithm to distribute the traffic through the network and size the links. In both methods outlined here, the assignment of the initial link blocking values and their subsequent manipulation are parts of the method and hence the values need not be specified to the program. Instead, however, both methods require the specification of the desired point-to-point loss probabilities which may be different for each point-to-point pair. For this reason, with either method, the fourth input will be desired point-to-point loss values instead of initial link blocking probabilities. The process of adjusting the input (link blocking values or link sizes) to the existing algorithm is shown in Figure 2.

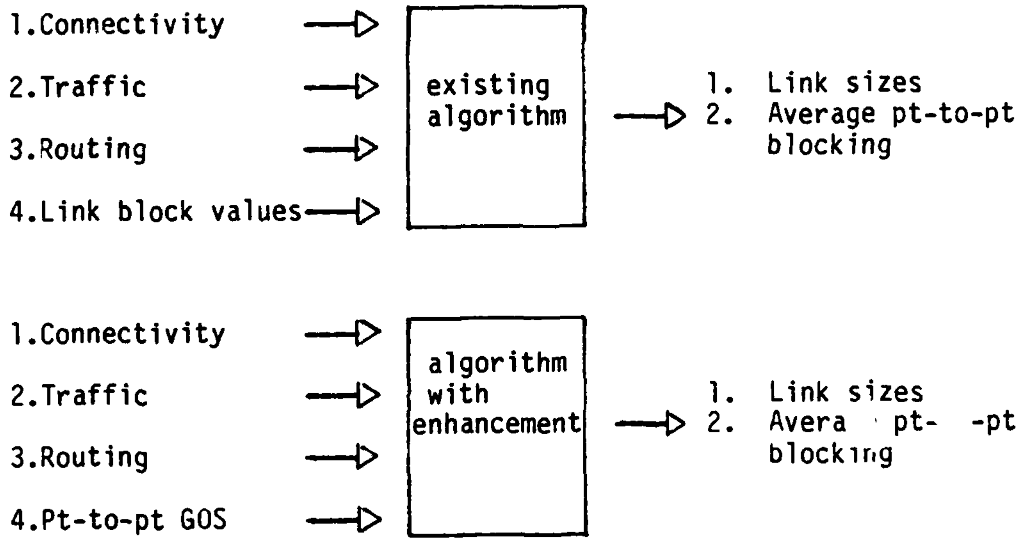


Figure 1. Inputs to the Existing Algorithm without and with Enhancement.

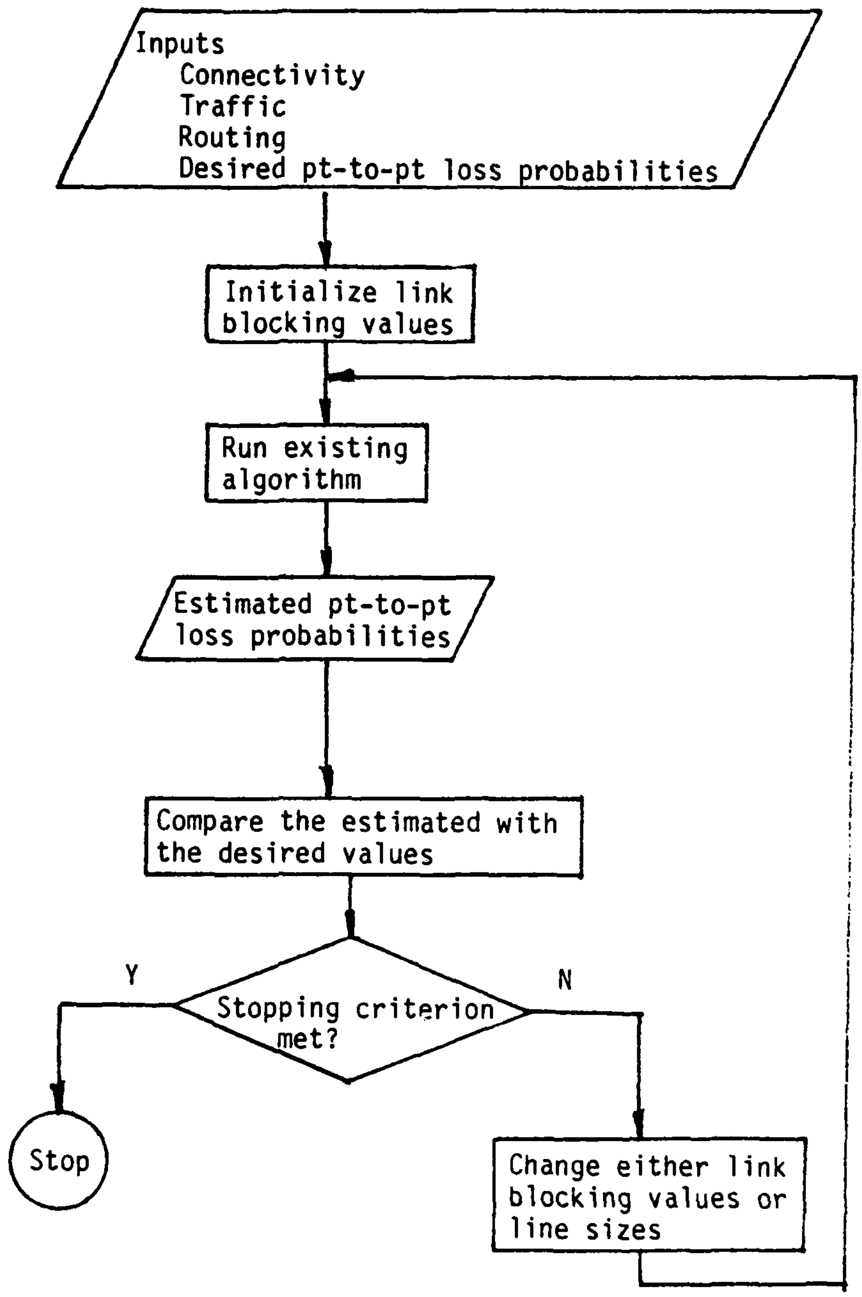


Figure 2. Flowchart of Adjusting the Inputs to the Existing Algorithm

II. OUTLINE OF THE METHODS

Both methods described in Section I are iterative, and for each iteration, the existing algorithm is run with a different set of either initial link blocking values or link sizes. The changes in this input are based on the deviations in the point-to-point loss probabilities estimated by the algorithm from the desired values. Outlines of both the methods, to be referred as the Link GOS Adjustment method (LGA) and the Link Size Adjustment (LSA) method, are given next.

1. LINK GOS ADJUSTMENT (LGA) METHOD

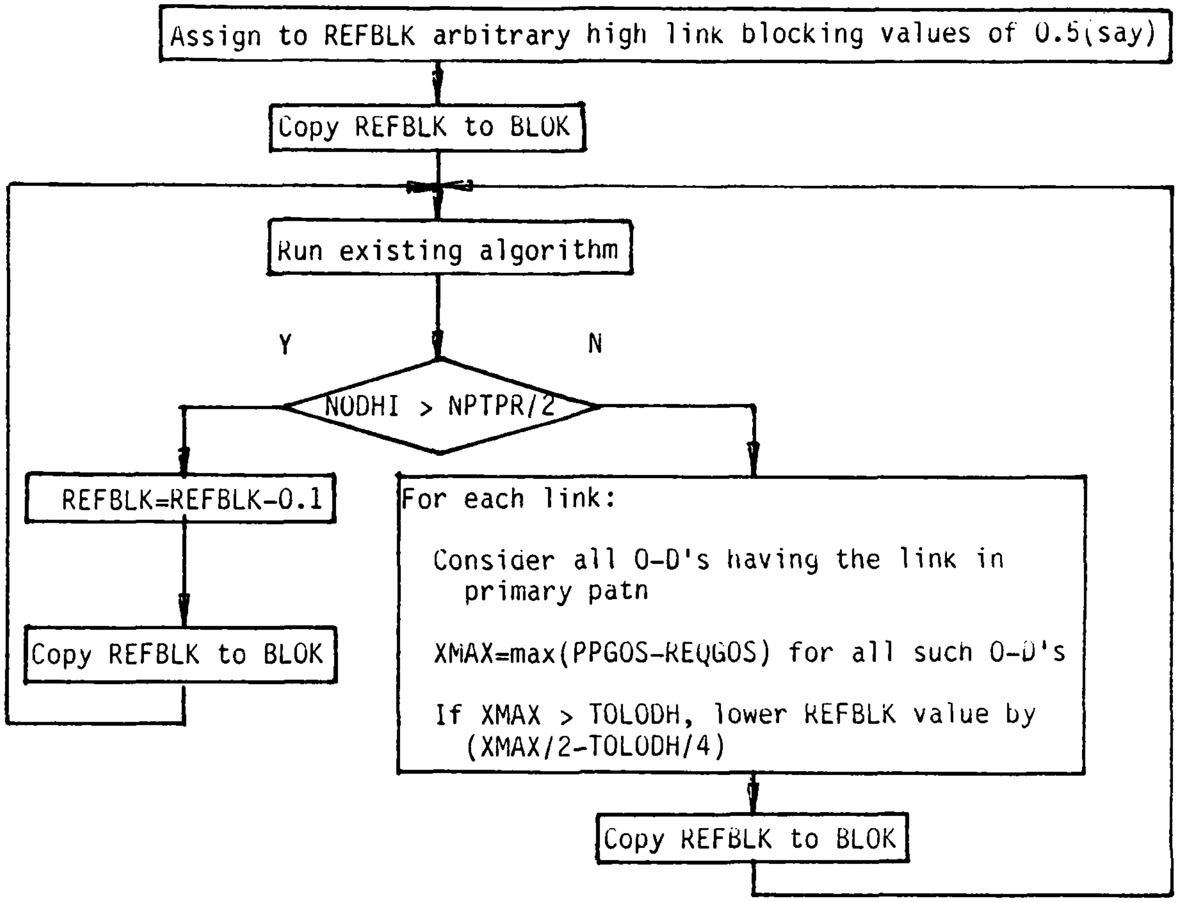
In each iteration, this method attempts to decrease the number of point-to-point loss probabilities that have exceeded specified upper bounds in the previous iteration. This is done by lowering the link blocking values of one or more links.

At the beginning, all links are assigned one high blocking value. During the initial iterations, this blocking value is lowered on all Links by a small fractional value (typically 0.1) until the number of point-to-point loss probabilities exceeding the upper bound values becomes less than a fraction (half) of the total number of origin destination pairs.

In the later iterations, the amount of adjustment to link blocking is determined individually for each link. For each link, the origin-destination pairs having that link in their primary path are considered and the maximum value, XMAS, of actual point-to-point loss probability minus the desired value is computed. If this value is greater than the allowed deviation (TOLODH) over the desired value (REQGOS), the link blocking value is decreased by half the maximum amount (XMAS) minus one fourth of the allowed deviation (TOLODH). Note that as several alternate paths exist for each traffic parcel, the resultant effect of adjustments to link blocking values on point-to-point loss probabilities is a complex one. When applied to the European AUTOVON network, this heuristic method of adjusting link blocking has performed better than other methods attempted in bringing the point-to-point loss probabilities below the specified upper bounds with the minimum total number of channels. The method is outlined in flowchart form in Figure 3.

With this method, the iterations will continue for a specified maximum number of times or until all the estimated point-to-point loss probabilities are within the specified upper bounds.

Note 1: In Figure 3, the initial values of 0.5 assigned to REFBLK are arbitrary; the value chosen, 0.5, is high enough for the estimated point-to-point loss probabilities to, in general, exceed the upper bounds. Decreasing the values of REFBLK in the subsequent iterations will, in general, lower the values of the point-to-point loss probabilities.



BLOK : link blocking probabilities input to the existing algorithm

LNKTOT: total number of links in the network

NODHI : number of O-D pairs with PPGOS > REQGOS + TOLODH

NPTPR : number of origin-destination pairs

PPGOS : pt-to-pt loss probabilities estimated by the existing algorithm

REFBLK: reference link blocking values, not affected by the existing algorithm

REQGOS: required or desired pt-to-pt loss probability values

TOLODH: allowed deviation (.015) in PPGOS over REQGOS value

Figure 3. Flowchart of Link GOS Adjustment (LGA) method

Note 2: Also, as shown in Figure 3, no REFBLK value is adjusted upward at any time, even when all the point-to-point loss probabilities of origin-destination pairs having a link in their primary paths are lower than the corresponding desired loss probabilities. All attempts incorporating the upward adjustment have failed to decrease the number of point-to-point loss probabilities exceeding their corresponding upper bounds.

2. LINK SIZE ADJUSTMENT (LSA) METHOD

This method was aimed at maximizing the number of origin-destination pairs whose point-to-point loss probabilities lie within specified lower and upper bounds, though some point-to-point loss probabilities may exceed their upper bounds.

The initial iterations are identical to those of the LGA method and involve lowering all link blocking values by a small constant fractional value.

In the later iterations, the method changes the link sizes and causes the algorithm to reestimate the point-to-point loss probabilities. Changing the link sizes is done in two steps, with the purpose of bringing the point-to-point loss probabilities (PPGOS) closer to the desired values (REQGOS). In step (1), on a temporary basis and as will be explained later, the traffic loads are changed, and in step (2) the link sizes are reestimated for the traffic loads in step (1). In other words, the links in the network are sized with traffic loads different from the specified values with the anticipation that the new link sizes will result in point-to-point loss probabilities (for the specified traffic) closer to the desired values. The principle used in altering the traffic loads in step (1) is based on the concept of an equivalent link, which is explained next.

Consider a source-destination pair (i.j) with loss probability PPGOS(i,j) that is not equal to the desired value REQGOS (i,j). The loss probability PPGOS (i,j) may be considered to be the effect of the network topology between (i,j), the current link sizes and the total traffic flow through the network. This effect may conveniently be represented by an equivalent link with a link blocking probability value equal to PPGOS(i,j). In other words, the carried traffic through the equivalent link is (1-PPGOS(i,j)) times the offered traffic (i,j), which is the same as that through the network between the nodes (i,j). As shown in Figure 4, the size of the equivalent link can be estimated from the offered traffic, OFFLOD(i,j) and the point-to-point loss probability PPGOS(i,j). Our purpose is to obtain a loss probability for the traffic parcel OFFLOD(i,j) equal to REQGOS(i,j). Theoretically, this can be done by changing the size of the equivalent link. The desired size will have a link blocking of REQGOS(i,j) when the offered traffic is OFFLOD(i,j). Or, if the link blocking is to remain the same as PPGOS(i,j), the new size will handle a different load, TOTLOD(i,j), which can easily be

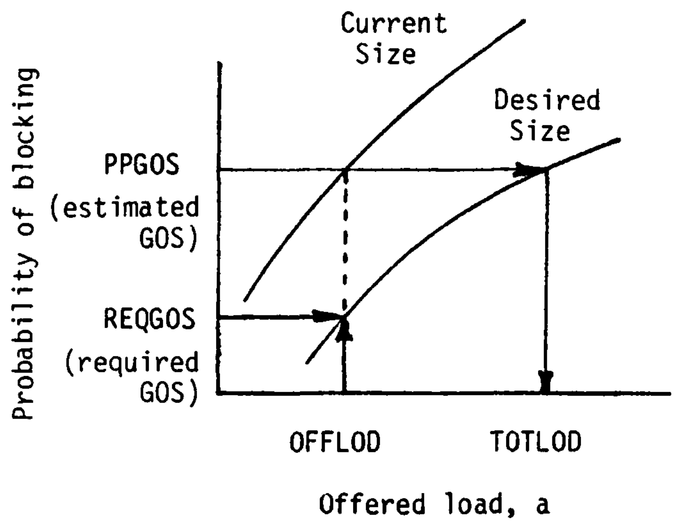


Figure 4. Calculation of Traffic Loads for the Purpose of Resizing the Links.

calculated from the values OFFLOD (i,j), REQGOS(i,j), and PPGOS(i,j). This forms the basis for changing the traffic loads for all source-destination pairs in step (1). To determine the link sizes in step (2), the values of the calculated traffic, TOTLOD, calculated in step (1), are used in subroutine LOAD to determine the link loads first, which are in turn used in the subroutine SIZE to determine the link sizes. To speed up the process, in each iteration, TOTLOD values will have been calculated and considered for all candidate links. However, to minimize the overlapping effect of changing the offered traffic for more than one source-destination pair at the same time, these amounts of changes need to be reduced. In a heuristic way, this is done as shown in Figure 5.

The iterations are repeated a certain number of times (=LNKTOT*3/8), and the link sizes maximizing the number of point-to-point loss probabilities, OFFLOD within the specified lower and upper bounds, (REQGOS - TOLODH, REQGOS + TOLODH) are selected.

Note that in Figure 5, as in the LGA method, the initial values of 0.5 for the REFBLK are arbitrary, but are chosen high enough so that estimated point-to-point loss probabilities will, in general, exceed the upper bounds. Decreasing the values of REFBLK in the subsequent iterations will, in general, lower the values of the point-to-point loss probabilities.

The expressions for the adjustment of OFFLD1 are arbitrarily determined by trial to maximize the number of point-to-point loss probabilities lying within their corresponding lower and upper bounds.

When compared to the existing method and to the Link Size Adjustment Method, the Link GOS Adjustment method has consistently given the lowest sum of trunks with the minimum number of estimated *point-to-point* loss probabilities exceeding specified upper bounds.

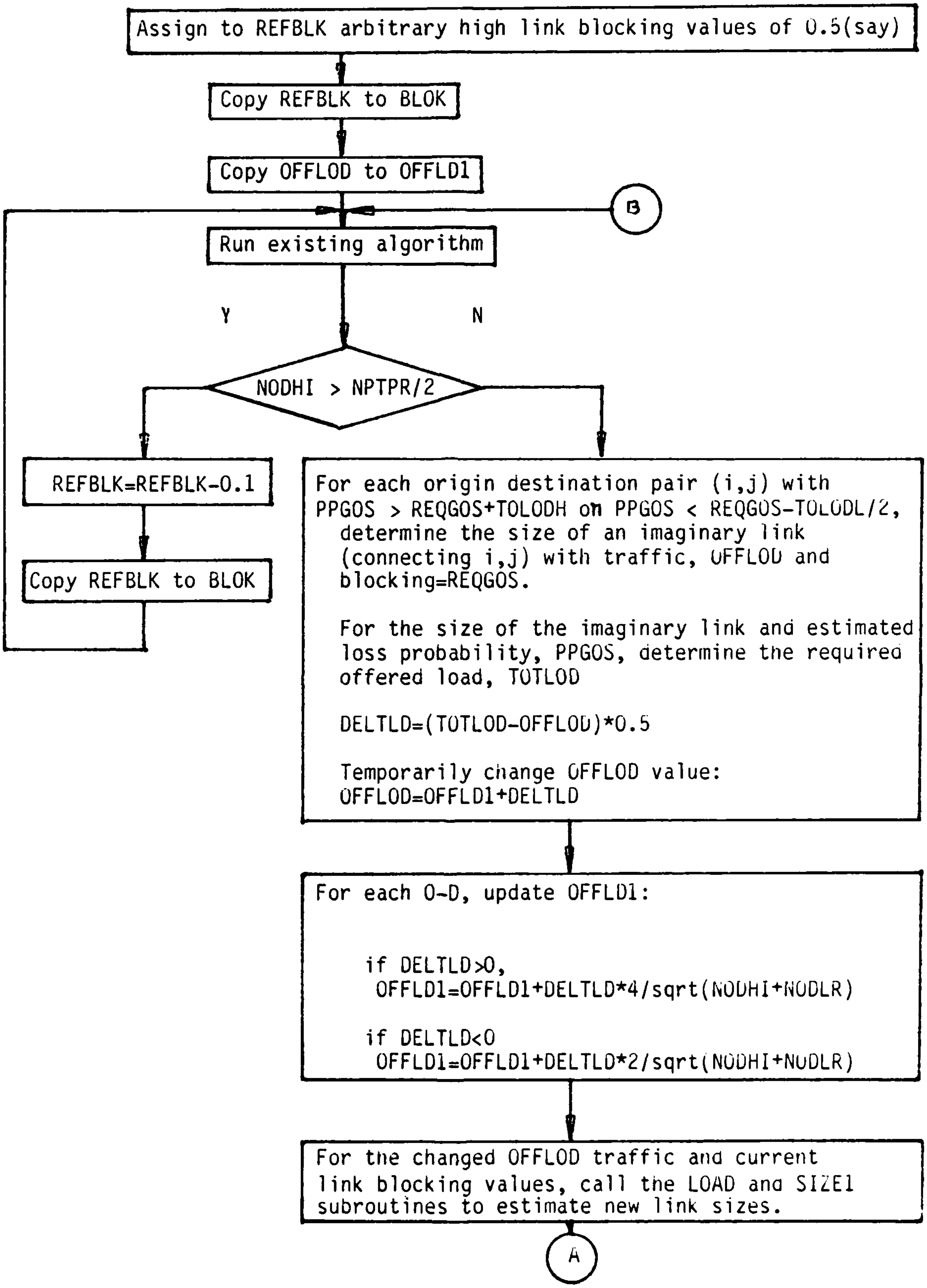
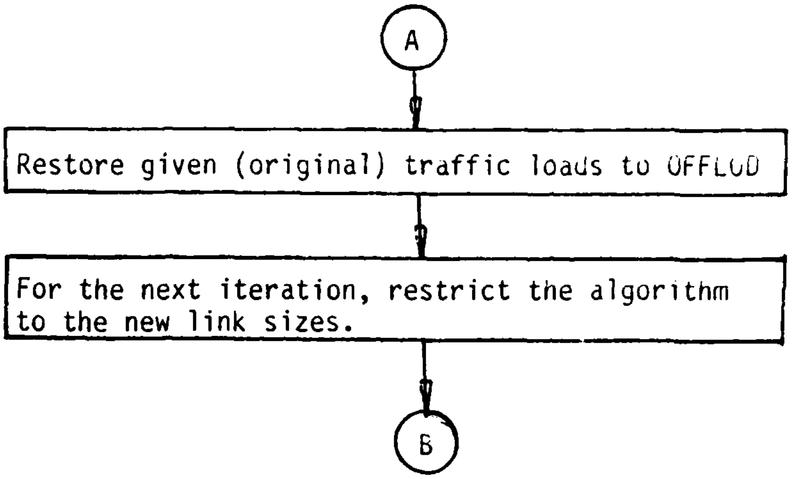


Figure 5. Flowchart of Link Size Adjustment (LSA) Method (1 of 2)



BLOK : link blocking probabilities input to the existing algorithm

LNKTOT: total number of links in the network

NODHI : number of O-D pairs with PPGOS > (REQGOS + TOLODH)

NODLR : number of O-D pairs with PPGOS < (REQGOS - TOLODL)

NPTPR : number of origin-destination pairs

OFFLD1: reference traffic loads, not affected by the existing algorithm, but used to artificially alter the traffic loads; initially set equal to given traffic loads.

OFFLOD: specified offered traffic

PPGOS : pt-to-pt loss probabilities estimated by the existing algorithm

REFBLK: reference link blocking values, not affected by the existing algorithm, but used to update BLOK values.

REQGOS: required or desired pt-to-pt loss probability values

TOLODH: allowed deviation (0.015) in PPGOS over REQGOS value

TOLODL: allowed deviation (0.03) in PPGOS under REQGOS value

Figure 5. Flowchart of Link Size Adjustment (LSA) Method (2 of 2)

III. COMPARISON OF RESULTS

1. INPUT DATA CONSIDERED

The given network consists of 13 nodes (with nodes #11, 12, 13 belonging to CONUS), 45 links (with three within CONUS), and 156 (13 x 12) origin-destination pairs.

For each origin-destination pair, the given routing plan allows up to a maximum of six alternate routes with an ordered preference. When media=2, for each pair of nodes connected, there exist both terrestrial and satellite links in parallel. When PERLOD is one, the offered traffic is as shown Table 1, and when PERLOD is three, the traffic is three times as great. The desired point-to-point loss probabilities are either .05 or .10, as given in Table 2.

2. DISCUSSION OF THE RESULTS

For the four sets of input data (Media=1,2 and PERLOD=1,3), the sum of link sizes obtained by the LGA and LSA method are compared with that of the existing algorithm as is (with initial link blocking values set to 0.127). The results obtained are summarized in Table 3.

From the results, the following inferences may be drawn:

(1) The Link GOS Adjustment method gave the best results, all the point-to-point loss probabilities could be brought below the specified upper bounds with the least value of the sum of the interswitch trunks. (For the last set of input data, with the LGA method, the number of the loss probabilities exceeding the upper bounds was one at the end of last iteration, and the job was terminated because it exceeded the limit on number of iterations.)

(2) The Link Size Adjustment method resulted in maximizing the number of point-to-point loss probabilities that lie within the specified lower and upper bounds.

(3) Compared to the LGA method, the LSA method, though the number of point-to-point loss probabilities above the lower bound is higher, still required a greater number of interswitch trunks. A close examination of the results for the first set of input data revealed the characteristics shown in Table 4.

(a) The number of hops/call is less in LGA method, which indicates that LGA method makes better use of given routing tables.

(b) Link Offered Loads: For all links, the link offered loads are higher in the LSA method, a reflection of the higher number of hops/call.

TABLE 1. POINT-TO-POINT (i to j) OFFERED TRAFFIC LOADS.

i= \ j=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	2.170	2.007	3.782	0.253	0.371	1.309	0.574	0.490	1.039	0.275	0.649	1.025	0.0
2	1.462	4.900	1.666	2.198	0.923	0.617	2.766	1.646	1.100	2.862	6.836	9.565	0.0
3	2.573	1.570	7.910	2.018	1.047	7.864	0.869	1.500	0.163	4.924	1.276	0.336	0.0
4	0.256	4.865	3.403	4.200	0.879	6.326	5.274	1.013	2.525	0.229	1.347	3.567	0.0
5	0.979	1.823	1.140	1.060	3.570	2.009	0.888	0.777	2.564	1.853	1.105	0.992	0.0
6	1.658	1.352	5.090	1.690	1.225	8.260	3.138	0.572	0.851	2.017	4.596	6.119	0.0
7	0.706	2.827	1.248	5.310	1.043	4.162	11.340	0.263	0.961	0.728	1.251	1.098	0.0
8	0.317	0.684	0.345	0.280	0.588	2.089	0.275	0.750	0.473	0.370	1.715	2.233	0.0
9	1.191	4.216	0.284	1.759	2.715	0.976	0.609	2.814	3.640	0.396	1.365	2.361	0.0
10	0.189	2.931	4.937	0.214	0.758	3.201	0.313	0.714	0.320	2.140	0.059	0.001	0.0
11	0.513	9.083	2.625	1.786	2.140	7.014	4.668	5.761	2.346	0.231	0.0	0.002	0.0
12	0.789	14.268	8.838	6.341	3.227	12.270	5.106	1.408	3.109	0.469	0.004	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 2. DESIRED POINT-TO-POINT (i to j) LOSS PROBABILITIES.

i= \ j=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.0	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.10	0.10	0.10	0.10
2	0.10	0.0	0.05	0.10	0.10	0.05	0.10	0.10	0.10	0.05	0.10	0.10	0.10
3	0.10	0.05	0.0	0.10	0.10	0.05	0.10	0.10	0.10	0.05	0.10	0.10	0.10
4	0.10	0.10	0.10	0.0	0.10	0.10	0.05	0.10	0.10	0.10	0.10	0.10	0.10
5	0.10	0.10	0.10	0.10	0.0	0.10	0.10	0.05	0.10	0.10	0.10	0.10	0.10
6	0.10	0.05	0.05	0.10	0.10	0.0	0.10	0.10	0.10	0.05	0.10	0.10	0.10
7	0.10	0.10	0.10	0.05	0.10	0.10	0.0	0.10	0.10	0.10	0.10	0.10	0.10
8	0.10	0.10	0.10	0.10	0.05	0.10	0.10	0.0	0.10	0.10	0.10	0.10	0.10
9	0.05	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.0	0.10	0.10	0.10	0.10
10	0.10	0.05	0.05	0.10	0.10	0.05	0.10	0.10	0.10	0.0	0.10	0.10	0.10
11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.0	0.05	0.05
12	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.0	0.05
13	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.05	0.0

TABLE 3. A COMPARISON OF THE PERFORMANCE OF LINK GOS ADJUSTMENT AND LINK SIZE ADJUSTMENT METHODS.

Load Factor	media	METHOD USED								
		EXISTING			LINK GOS ADJUSTMENT			LINK SIZE ADJUSTMENT		
		(IST)	α of pt-to-pt loss probabilities		(IST)	α of pt-to-pt loss probabilities		(IST)	α of pt-to-pt loss probabilities	
			>upper bound	within bounds		>upper bound	within bounds		>upper bound	within bounds
1	1	498	3	4	476	0	39	481	31	78
1	2	109(T) +431(S)	0	2	119 +352	0	20	95 +398	13	74
3	1	1,284	4	8	1,265	0	42	1,362	25	78
3	2	208 +1,095	2	2	261 +948	1	28	212 +1,145	27	71

Note: (T) Total number of terrestrial channels
(S) Total number of satellite channels

TABLE 4. A COMPARISON OF THE LINK CHARACTERISTICS WITH THE LINK GOS ADJUSTMENT AND LINK SIZE ADJUSTMENT METHODS.

	Intra area(1)		Inter area(1)		Total	
# of links(2)	8		34		42	
# of O-D pairs(3)	20		112		132	
Method	LGA	LSA	LGA	LSA	LGA	LSA
# of pt-to-pt loss probabilities:						
below lower bound	2	2	91	34	93	36
between bounds	18	16	21	60	39	76
above upper bound	0	2	0	18	0	20
Avg. link load	18.1	21.2	11.7	18.3	12.9	18.8
Avg. link blocking	0.24	0.19	0.32	0.49	0.30	0.43
Avg. link size	17.0	21.3	10.0	9.5	11.3	11.8
# of links with						
higher link load	0	8	0	34	0	42
higher link blocking	6	2	5	29	11	31
higher link size(4)	0	8	21	10	21	18
# of hops per call	-	-	-	-	1.42	1.63

Note: (1) Overseas European network was divided into four areas, excluding CONUS.
(2) The three links within CONUS are excluded.
(3) Origin destination pairs within CONUS and node 13 to other nodes are excluded.
(4) Three of the 34 links have same size in both LGA and LSA methods.

(c) Link blocking: For intra-area links, the link blocking is higher in LSA method for only 2 out of 8 links, whereas for interarea links, the link blocking is higher for 29 out of 34 links.

These characteristics probably result because the point-to-point loss probabilities chosen for intra-area (.05) were less than for interarea (.10). These differences are better reflected in the Link Size Adjustment method (LSA),on the intra- and interarea average link blocking values.

(d) Link Sizes: In the LSA method, all intra-area links have higher link sizes, whereas most interarea links have smaller sizes. As interarea links are likely to be more expensive, interarea origin-destination points may be allowed higher loss probabilities. If this happens to be the case, the LSA method has the potential for reducing the overall network cost better than the LGA method, though it may mean that some point-to-point grades of service may be inferior to specified requirements.

IV. CONCLUSIONS

This report outlines two methods of automating the calculation of link sizes. Both methods are applicable to circuit-switched network problems where the network connectivity, traffic loads, routing tables and desired point-to-point grades of service are known. Using test data, the Link GOS Adjustment method gave a lower sum of interswitch trunks. However, when interarea switch trunks are more expensive and lower interarea point-to-point grades of service can be tolerated, the Link Size Adjustment method could result in lower overall network cost. For this reason, it is recommended both the methods be tried when sizing the links.

REFERENCES

S. S. Katz, "Statistical Performance Analysis of a Switched Communications Network," Fifth Teletraffic Congress, New York, June 1967.

NOTATION

BLOK	Initial link blocking probabilities
GOS	Part of the name of a method; refers to link blocking probability.
LGA	Link GOS Adjustment method
LNKTOT	Total number of links in the network (45)
LSA	Link Size Adjustment method
NODHI	Number and source-destination pairs with loss probability above the upper bounds
NODLR	Number of source-destination pairs with loss probability under the lower bounds
NPTPR	Number of source-destination pairs (156)
OFFLD1	Surrogate of traffic loads; manipulated outside the algorithm
OFFLOD	Specified source-destination offered traffic
PPGOS	Point-to-point loss probabilities, estimated
REFBLK	Surrogate of link blocking probabilities; manipulated outside the algorithm
REQGOS	Desired source-destination point-to-point loss probabilities
TOLODH	Acceptable deviation (.015) in point-to-point loss probabilities over the desired values
TOLODL	Acceptable deviation (.03) in point-to-point loss probabilities under the desired values

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